ELEMENTS OF SIDEREAL SYSTEM.

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Hitherto the work of Astronomy has been mainly on our solar system. Beyond this the labor of astronomers has been given to individual stars; but not to these stars as a body forming our sidereal systen. The time has now come when the sidereal system as a unit must be made in all its vastness a distinct object of investigation. I have demonstrated that our sun acts powerfully through gravity on the so-called fixed stars, and must receive powerful action in return. This mutual interaction between all the stars would bring them with great violence to this common centre of gravity, and therefore they must revolve with high velocities around that centre to gain a corresponding centrifugal force. Now first we learn the uses of such high velocities as those of 61 Cygni and of Arcturus, the one nearly 2000 and the other nearly 3000 miles per minute. In my Memoir on "Our Sidereal System," published in these Proceedings for 1876, I demonstrated that the centre of gravity of our sidereal system, around which all the stars revolve, must lie in the plane of the median line of the galaxy, that its direction is not far from the south galactic pole, and that its distance is not far from that of the stars of the fourth magnitude. Therefore the vast multitude of the stars visible to the naked eye, say five-sixths of them all, must lie on the same side of the centre of gravity with our sun.

This distance of our situation, so far away on one side of the centre of our sidereal system, renders the study of that system the more difficult; the same as our similar position in our solar system, far away from its centre, hindered and rendered difficult the reception of the Copernican theory for two generations. But now, knowing approximately the position of our sidereal centre, and the geometrical data by which that centre was found, we are prepared to enter on the grand work of sidereal astronomy, and to study the revolutions of twenty millions of stars. In building the superstructure of sidereal astronomy on the foundation just laid, it is important to know precisely how to proceed; and the design of this paper is to point out how and where we are to begin; and what are to be the chief parts of the work. In so

doing I will merely state what have been my own studies on this subject a few years past.

First. After learning the proper motion of a star, the first thing to be done is to lay down the line of its nodes on the plane of the galaxy. This is in many cases a most difficult task. But the easier ones are to be determined first; and these are situated in the close neighborhood of both galactic poles. After the proper motions within 30 degrees of both poles have been finished, as nearly as possible for the present, then the other proper motions more distant from these poles will be more advantageously studied.

Second. The galaxy must be divided into 360 degrees; because the galactic plane must be the basis of sidereal astronomy; and to this all sidereal motions must be referred. I propose that the initial point for numbering the degrees on the galactic circle be the point where the median line of the galaxy intersects the ecliptic, near the convergence of the three bright constellations, Orion, Gemini, and Taurus. From these the numbers should run south-eastwardly until the galactic circle be completed.

Third. The median line of the galaxy should be precisely determined. This is necessary before we can tell where it intersects the ecliptic. This median line must be conspicuously drawn on all star maps and celestial globes, and the galactic degrees must be numbered thereon. Its distance from a parallel great circle must be accurately maintained all around. For on this distance depends the determination of our own distance from the sidereal centre. All this will necessitate a careful study of the galaxy—its breadth, contours, and real position among the stars.

Fourth. After finding as nearly as possible the line of the nodes of any star on the galactic plane, the next thing to be done is to determine the inclination of its orbit to that plane. Here again we find that the stars easiest to begin with, are those nearest the galactic poles. The planes of their orbits are nearly at right angles to the plane of the galaxy.

Fifth. After the median line of the galaxy has been ascertained and accurately drawn, we can then, and not until then, determine the positions of the galactic poles.

Sixth. After establishing the sidereal poles, it will be important that we construct sidereal globes, having parallel circles concentric with the poles, and also meridian lines. These will assist in the very important work of finding the lines of the nodes, and the

inclinations of the orbital planes. The numbering of the meridians should begin at the intersection of the median line of the galaxy in or near Orion; and the numbers should be identical with those on the median line of the galaxy. The numbering of the parallels should begin at the north galactic pole, and continue to 180°. They should read S. N. P. D., that is, sidereal north polar distance. As the object of these sidereal globes must be to discover the real nature of sidereal motions, so those stars alone which have known proper motions should be admitted on the globes. All else would only confuse the attention and obstruct discovery.

Seventh. To discover which way around the Milky Way revolves, is a grand object. It must revolve in its own plane like a great wheel. This is absolutely necessary from the fact of the intergravitation of the stars. But with the swiftest stellar velocities yet known, say 3000 miles per minute, about 40 years would be required for the galactic stars to move through one second of arc. Therefore we have no present data to learn anything of the galactic revolutions from its own stars. Hence to attain our purpose, we must study the motions of the larger magnitude stars which are situated in the direction of the galaxy. Because many of these must have the same motion as the galaxy itself, especially those far out toward the galaxy; therefore, the more distant stars in the direction of the galaxy, especially those with very slow proper motions, will give us the most information.

Eighth. One of the fundamental elements in sidereal astronomy is the point in space toward which our sun is tending. The high importance of this element is seen in the fact that our sun's motion obscures and alters the apparent motions of many stars, giving some of them retrograde motions, the same as our Earth's motion in its orbit imparts retrograde motions to the planets.

Some astronomers of the highest repute have entertained the opinion that our sun is moving toward a point in the constellation Hercules. But this opinion is founded on the supposition that all, or nearly all the stars, are relatively stationary in space, and that their observed proper motions are only apparent, and that they are caused by our sun's motion. But this supposition is above all things inadmissible; for there is no conceivable reason why all the other stars should not in general have velocities equal to our sun's. Nevertheless, the discussions on this point may

not be altogether barren; for the facts detected in the discussions may be turned to better account with a better theory.

I have clearly shown in my former paper on "Our Sidereal System" that the point in space toward which our sun is moving, must be sensibly the same during two or three centuries, that is, during all the time in which the positions of the stars have been accurately observed and recorded. I submit the following as being a better guide for finding that point. As the circumference of a circle, more strictly speaking a tangent, is always at right angles to a radius, so the direction of our sun's motion, if its orbit be nearly circular, must be nearly at right angles to the direction toward the centre of our sidereal system. Having found that centre approximately, we now know the zone in the heavens, included in a few degrees on each side of a great circle, where to look for the point in space to which our sun is hastening. But if the sun's orbit be strongly elliptical, and if its present position in that orbit be not near the apsides, then this zone in the heavens must be a little widened. Still, even if widened, we may be happy to know where it lies. It must correspond very nearly with the galaxy. This results from the fact that the direction toward our sidereal centre is nearly perpendicular to the galactic plane. Any point in the constellation Hercules cannot be the point we seek, for it is too far from the galaxy.

Ninth. It will be an assistance to workers in sidereal astronomy to make what may be called sideriums. These should stand in the same relation to our sidereal system, that planetariums hold to our solar system; but their structure must be very different from planetariums. We have all seen during our recent centennial celebration many little flags with their staffs stuck in a central ball; and as their staffs were all of the same length, they formed a globe of little flags. A siderium must have a central ball made of soft wood or cork. In this ball must be stuck thin sharp-pointed rods, and their outer ends, instead of flags, should bear paste-board arrows, representing the directions of stellar flights. On the arrow should be written, or printed, the name of the star, as 61 Cygni, and the different lengths of the arrows might aid to show their relative velocities. The lengths of the rods should show the relative distances of the stars from the sidereal centre. In the cases of two stars of the second magnitude, one in the direction of our sidereal centre, and the other in apposition, the

lengths of the rods holding the arrows should bear the proportion to each other of about as 1 to 3. The positions and inclinations of the rods should represent the inclinations of the stellar orbits to the galactic plane. The galaxy should be represented by a circular rim held at some distance beyond the arrows, by about 4 supporting radii or spokes.

Tenth. All the star catalogues should be immediately compared to learn the precise amount of their known proper motions and to discover new ones. It is now 28 years since any general work of this kind has been done. Main's catalogue of proper motions was presented to the Royal Astronomical Society in 1850. Since then all the more accurate observations and star catalogues have been made, and therefore, more valuable results might now be obtained. Comparisons of the recorded positions of the southern hemisphere stars are particularly needed; for in that hemisphere but little is known of the stellar motions.

Eleventh. New observations should immediately be made of every star whose proper motion has been announced, or even suspected; this would give accuracy, firmness, and confidence to the data which must be employed in the construction of this new system of sidereal astronomy.

Twelfth. In order to determine which way the galaxy wheels around in its mighty circle, it is of the utmost importance that the positions of many hundreds of its stars should be ascertained with the strictest precision and without any delay. This would be of no benefit to us; but what a rich legacy would such determinations be to the next generation, and how memorable would they stand through all coming time! Hipparchus was the first to make a catalogue of a few hundred stars, and to record their positions, and he receives our sincere gratitude and homage. Who is to be the Hipparchus of the Milky Way, and to send down a blessing through all generations to the end of time? What a worthy object for any young man to propose for the devotion of his life! All the stars of the galaxy cannot be observed, on account of their numbers. But maps of different patches should be made here and there all around the ring. The stars of different magnitudes from the ninth to the twelfth, and even to the very smallest, should be mapped together, so that hereafter the velocities of the different magnitudes, that is, of different distances, might be compared.

Thirteenth. Sidereal mathematics will open new problems of exceeding grandeur. In our solar system there is a controlling central sun, and in the mundane and other planetary systems, there is a controlling central planet. But our sidereal system is ruled by no central sun, and its subordinate clusters, such as the Pleiades, Coma Berenicis, those in Hercules, and many others are equally without a central body. The common centre of gravity in the general system, and the subordinate local centres in the various clusters, are the controlling powers. And they will demand new mathematical processes, and lead to new improvements in mathematical science.

I have demonstrated how a revolving nebulous globe may abandon all its material as rings, which may break up into stars, and how these stars must continue to revolve in the same paths with the rings until they be deflected from these paths by perturbations.

One of the sublime problems of sidereal astronomy will be the amount of centripetal force in the entire sidereal system. This must be told by the centrifugal force, and this latter will have to be determined by the velocities of the stars in their revolutions, and by their distances from the sidereal centre. Judging from the extreme velocities of some stars, velocities of 2000 or 3000 miles per minute, velocities greater than any in our solar system, we must conclude that the common centripetal force toward the centre of our sidereal system is very great.

In our solar system the centripetal force is greater toward the centre of the system; but this is not true in our sidereal system. A particle a hundred or a thousand miles below the earth's surface, is not impelled by gravity toward the earth's centre, as strongly as one on the surface—the same principle rules in our sidereal system.

As the asteroid Pallas has been drawn by perturbation as far as about 35 degrees from its original plane, so it can be shown that perturbations may deflect some stars away from the galactic plane so as to revolve at right angles to it. Other stars may be deflected equally far in the opposite direction. Then these two sets of stars will revolve in opposite directions around the sidereal centre. And when this happens to many stars, the system must become globular in shape, like many nebulæ which are distant sidereal systems. The dynamics of such systems must be new

objects of mathematical research, especially in the face of the announcement, that the stability of our solar system depends on the movements of all its members in the same plane, and in the same direction.

When two stars move with high velocities, in contrary directions, around the sidereal centre, and approach near to each other, they will not come in contact, unless their lines of motion meet at the same time in the same point; but they may come indissolubly within each others' gravitating force, and thus form a double star. So triple stars may be formed, and multiple stars, and clusters with hundreds and even thousands of members.

The ultimate revolutions of such clusters, each one around its own centre, and altogether around the general sidereal centre, are absolute necessities. These motions must be the resultants of the prior individual motions, and of the effects of gravity from closer contiguity. To follow them all by calculation will be a new and difficult task. This paper is not designed to pursue these mathematical processes, but only to indicate some of the new and grand problems which sidereal astronomy must open; problems very different from any in our solar system.